SPATIAL BEHAVIOR IN SAN FRANCISCO'S PLAZAS
The Effects of Microclimate, Other People, and Environmental Design

JOHN ZACHARIAS *received his B.A. from the University of Saskatchewan, his M.A. in urban planning from the University of British Columbia, and his Ph.D. in planning from the Université de Montréal. He is currently a professor and chair of the geography, planning, and environment department at Concordia University. He has published in the fields of environment-behavior relationships, urban design, and environmental aesthetics.*

TED STATHOPOULOS *received his civil engineering diploma from the National Technical University of Athens, Greece, and both his M.E.Sc. and Ph.D. from the University of Western Ontario. He is currently a professor and associate dean of the School of Graduate Studies at Concordia University. He has carried out research and published extensively in the areas of wind effects on buildings and environmental aerodynamics. He is a fellow of the Canadian Academy of Engineering.*

HANQING WU *received his B.Sc. (mechanics) and M.Sc. (fluid mechanics) from Beijing University, China, and his Ph.D. (building studies) from Concordia University, Canada. He is now technical director in microclimate studies at RWDI Inc., specializing in pedestrian-level wind, thermal comfort, air quality, rain infiltration, snow drifting, and accumulation.*

ABSTRACT: This observational study of plaza-user behavior in San Francisco is intended first to determine whether behavior is invariant across different microclimatic regimes. Statistical behaviors in the present study are indistinguishable from those observed in a previous study, holding constant the microclimatic conditions in the two cases. Certain social behaviors are examined in relation to response to microclimatic conditions. The presence of smokers had no effect on the distribution of users and activities. However, when preferred environmental conditions were in limited supply, users accepted slightly higher levels of crowding in the preferred condition. When a threshold density of persons was reached, users opted for less ideal conditions, moving into the preferred condition when space became available. The

ENVIRONMENT AND BEHAVIOR, Vol. 36 No. 5, September 2004 638-658
DOI: 10.1177/0013916503262545

provision of seating had no impact on use level, whereas a redesign to provide sheltered seating had a modest positive impact. In this study, environmental design had minor effects in relation to microclimate.

Keywords: *open space; microclimate; spatial behavior; public space; behavior mapping*

In a previous study (Zacharias, Stathopoulos, & Wu, 2001), observed spatial behavior in downtown open spaces was related to microclimatic conditions. It was found that temperature has a preponderant effect on presence, combining positively with sunlight and negatively with wind through a threshold temperature of 22 °C, whereon public presence in sunlight begins to decline, along with overall presence in public space. These data provided nonlaboratory evidence of approach-flight response that has been observed in a variety of laboratory and natural settings and for several environmental stimuli. Recent examples include the relationship between temperature and violence (Rotton & Cohn, 2000), odor and annoyance (Liden et al., 1997), noise in relation to annoyance (Stallen, 1999) and to cognition and aesthetic appreciation (Mace, Bell, & Loomis, 1999). The nonlinear response to environmental stress in humans is of considerable interest for a number of reasons. For example, objective measurements of stress may not correspond with perceived stress because people respond selectively to environmental stimuli (Dosher & Lu, 2000). In a variety of situations where ability to perform tasks successfully and safely is crucial, we need measurement scales that reflect human experience. In the case of microclimate, the effects of solar heat gain, high humidity, and air movement on comfort can be predicted from physiological models but may not correspond with perceived comfort. It is also suggested that environmental learning may be important in response to ambient environmental conditions. Acclimatization may be responsible for changes in spatial behavior after a period of time. Differences in spatial behavior across cities with different climates also suggest differential response to the same ambient conditions, although these variations do not prove that ambient conditions are responsible (Koushki, 1988; Tanaboriboon, Hwa, & Chor, 1986; Walmsley & Lewis, 1989).

Sunlight and light components of microclimate in particular have important physiological and psychological effects. Exposure to sunlight reduces depression and the length of depressive episodes (Benedetti, Colombo, Barbini, Campori, & Smeraldi, 2001). Even though specific negative effects

AUTHORS' NOTE: *The authors thank the Seagram Foundation for Academic Excellence and the Social Sciences and Humanities Research Council of Canada for their financial support for this research. Tim Blair conducted most of the field studies.*

of direct exposure to harmful solar rays on physical health are established, overall human health is enhanced with exposure to sunlight and light (Butler & Nicholson, 2000; Roberts, 2001). The availability of sunlight in the working environment may be particularly important, given the negative effect on morale, attendance, and intentions to stay in workplace found in studies of deprivation of access to the outdoor environment (Leather, Pyrgas, Beale, & Lawrence, 1998).

Although the 2001 plaza study demonstrated the preponderant effects of microclimate in the spatial behavior of users of open space, the study did not demonstrate the importance of these environmental variables in relation to others, such as crowding, the presence and behavior of other users, and environmental design. Simply put, when choice is unconstrained, people tend to refer to microclimatic conditions when deciding where to spend time and in which activities to engage. How will people respond in situations of limited supply of preferred conditions? Although this question is of practical importance in the present case, it is also of considerable theoretical interest in helping us understand how we make behavioral choices.

This article addresses three issues: First, is the response to microclimatic condition invariant across microclimatic regimes? The response, measured in terms of spatial behavior of plaza users in San Francisco, is compared with that uncovered in Montreal. Second, when faced with a limited supply of the most preferred environmental condition, will people respond by crowding into the preferred space or move into less desirable space? Does the presence of smokers further constrain the spatial choice or otherwise affect the distribution of people over space? Third, we would like to know whether environmental design mitigates for less than ideal microclimatic conditions, as is suggested by some planners. This last question is addressed by examining the behavior before and after a redesign of a plaza and by examining plaza-use level in relation to the supply of seating.

THE SAN FRANCISCO CASE STUDY

In 1985, San Francisco introduced some of the most stringent requirements ever legislated in North America to manage the microclimatic environment of privately owned public space (City and County of San Francisco, 1985). Accessible, open spaces were required in all new office building projects, and the microclimatic environment of existing privately owned spaces was also protected. In several cases, the heights and volumes of new buildings were severely reduced from permissible levels to protect plazas already in existence in the downtown area. These requirements were widely publicized, discussed in the academic legal literature (Vettel, 1985), and emulated in many cities, including Montreal. The 1985 plan was a response to perceived overbuilding in downtown San Francisco in the decade following the 1969 urban design plan. Tall, bulky buildings reduced sunlight on plazas and contributed to air turbulence. It was argued that the particular environmental conditions of San Francisco merited a special approach to the management of the microclimate (Cherulnik, 1993). In particular, cool temperatures throughout the year, a humid breeze from the Pacific Ocean, and frequent sea fog were thought to justify extensive protection for sunlight in public plazas.

When cities negotiate open-space requirements with developers, they typically grapple with choosing between more open space and space of higher quality. In densely built-up downtown areas, light, sunlight, and shelter from wind and turbulence are already at a premium. In typical situations, planners must choose between maximizing the opportunity for space acquisition and reserving smaller spaces that provide ideal location and microclimatic conditions. In practical terms, Will people crowd into those smaller spaces of higher quality? Are there lower limits to personal space in downtown plazas (Hall, 1966), which, when reached, lead people to move into a public space of lower environmental quality? Might they forego the plaza visit entirely should they be unable to enjoy it in physical and psychological comfort? Although privately owned public space is physically attached to buildings housing workers, who constitute most of the open space users, those users may choose among several or many open-space alternatives. In an environment such as downtown San Francisco, where sunny, protected outdoor space is relatively scarce, we may determine the extent to which people will crowd into those preferred areas or, alternatively, forego physical comfort for the sake of psychological comfort. From the public policy standpoint, if people readily make such compromises with physical comfort, then it may be suggested that maximizing the amount of public open space or focusing on its design are more important than obtaining places with excellent microclimatic characteristics. Understanding the relationship between microclimatic conditions and spatial behavior does not allow planners to decide on the relative weight to accord factors such as location, landscaping materials, view, microclimate or on-site services. For this additional reason, we attempt to establish the importance of the amount of open space in relation to its microclimatic regime, using human behavior as criteria.

The effect of design on human behavior can also be evaluated by observing behavior before and after the design change. One of the plazas underwent a major design transformation to promote public use after our first public-space survey. The bench and planting groups of this redesign have become a

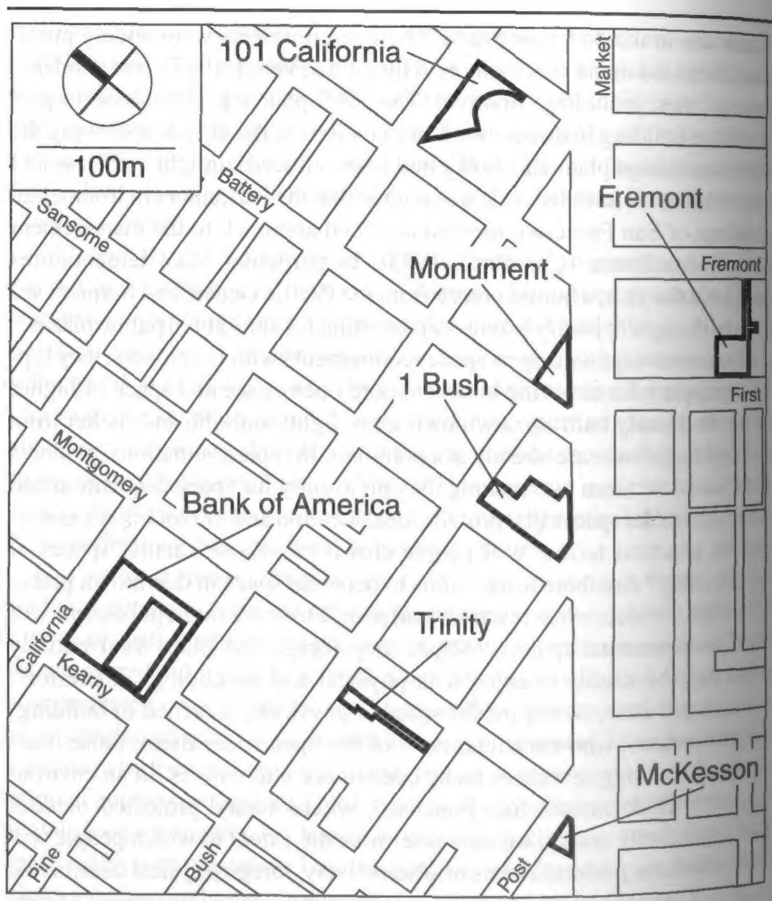

Figure 1: The Seven Plazas in San Francisco Where Observations of Spatial Behavior Were Carried Out

standard solution everywhere. Benches are now included in nearly all privately owned public space and often must meet stringent standards for ergonomic comfort. The standards in San Francisco specify both the number and type of bench, although the majority of the plazas studied were actually created before such standards came into effect. In our case, we look at the effect of seating provisions on plaza use versus microclimatic condition.

As in the Montreal study, seven privately financed and owned plazas closely spaced in the downtown core were selected for the observation study (see Figure 1). At each periodic census, every person in the plaza was recorded in position standing, sitting, or smoking a cigarette. Sunny and

shaded areas were drawn on the map. Air temperature readings were taken in the shade at a central position in the plaza, and wind conditions were recorded subjectively at three levels, corresponding to no perceivable wind, slight wind, and considerable wind. Surveys were not conducted in the rain. The data were recorded continuously over a period spanning from 11:30 a.m. to 3:00 p.m. on weekdays by one trained observer, who moved between the spaces. A total of 347 plaza censuses and 12,378 individuals were recorded during the months of February, March, and April 1994 and during February and March 1998. The Montreal study was conducted in April, May, June, September, and October, using the same daily schedule. Times of year with marginally good conditions for outdoor activity were chosen to try to ensure that we would be observing daily variation in behavior in accordance with variable conditions.

The behavioral data were transferred to a Geographical Information System (GIS). A single regression equation for spaces, times, temperature, sun, shade, and wind was derived from this set and compared with the 2001 equation. The relationship between sunlight and human presence was explored. In particular, the nonlinear nature of this relationship was investigated as a way of understanding how social factors interact with microclimatic factors in behavior. Similarly, human density was calculated for sunlit and shaded areas over all spaces and times. We were also able to test the impact of one design on behavior while controlling for microclimate. A standard *t* test was conducted for presence in the redesigned part of the plaza before and after implementation of the design and in relation to presence in the rest of the plaza. Finally, the effect of seating provision was tested by measuring the total length of seating in sun and shade, counting the number of people seated in both conditions. Multiple regression analysis was performed to uncover the importance of seating provision in presence.

PLAZA MICROCLIMATE AND PUBLIC PRESENCE

The recorded air temperature varied from 11.7 °C to 23.3 °C, with a median temperature of 15.2 °C. Presence in the plazas recorded in 1998 (see Table 1) follows the familiar bell curve over time, with a single peak between 12:30 and 1:00 p.m., although presence level varies considerably among the seven plazas (see Figure 2). There are some obvious differences in user groups among the plazas. For example, Monument Plaza has a highly diverse clientele, including homeless people, whereas 1 Bush Plaza is also the main dispatching base for the city's messenger corps.

TABLE 1
Summary Data on the Seven San Francisco Office Plazas, 1998

Plaza	Censuses Number	Total Number of People	Number of People Smoking (%)	Mean Presence	Mean % Area in Sun
Monument	53	1,448	70 (4.8)	49	50
101 California	53	1,351	22 (1.6)	25	7
Bank of America	53	2,456	153 (6.2)	46	30
McKesson	52	2,549	4 (0.15)	48	55
Trinity	50	768	65 (8.5)	15	15
Fremont	36	1,335	17 (1.3)	37	58
1 Bush	50	2,471	3 (0.12)	49	28

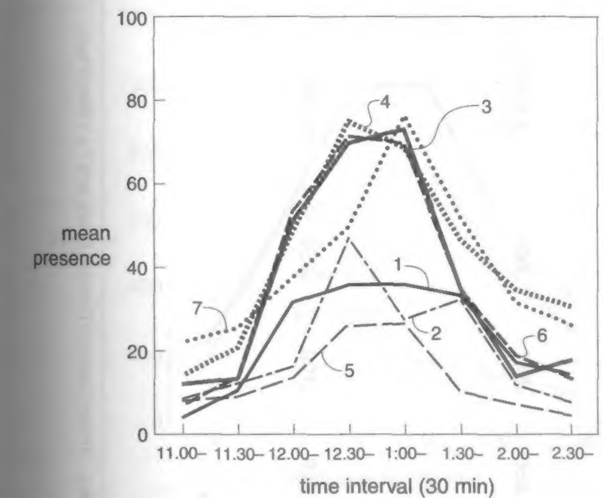

Figure 2: Mean Presence in Downtown Open Spaces Over Time
NOTE: 1 = Monument Plaza; 2 = 101 California Plaza; 3 = Bank of America Plaza; 4 = McKesson Plaza; 5 = Trinity Plaza; 6 = Fremont Plaza; and 7 = 1 Bush Plaza.

As in the Montreal case (2001), the presence data were divided into 30-minute temporal periods, corresponding to the major variations in presence observed in plazas from 11:00 a.m. to 3:00 p.m. The relationships between the number of people in seven open spaces and the microclimatic variables, open space and time of census are presented in Table 2. The microclimatic variables, open space and time of census are coded with dummy variables and multiple regression, and ANOVA tests were carried out. Microclimatic variables account for about 11% of the variance, place accounts for 7%, and time accounts for 11%. These components of variance compare with 12%, 38% and 7%, respectively, in the Montreal study. Although it would be expected that the importance of place in spatial behavior would vary across cities, the nearly identical role of microclimate is of considerable interest here. Also, as shown previously, the presence of wind reduces public presence in plazas across the temperature range experienced in San Francisco. The coefficient for sun at 14.5 is substantially greater than for the Montreal study, a point that is examined later in this article.

Two temperature ranges from the 1998 data set are examined in detail, 11.7 °C to 15.5 °C ($n = 125$) and 15.5 °C to 20.5 °C ($n = 125$), with all individuals standing and sitting counted separately (see Figure 3). Although total presence is consistently higher at the higher temperature range across the midday time intervals, the proportion of people sitting is also higher at these

TABLE 2
Analysis of Presence in Public Open Spaces

Multiple Regression Variable	Regression Coefficient	t Value	R	R^2	Adjusted R^2	ANOVA F Value
Microclimate			.266	.071	.062	7.635**
Sun	14.515	8.654**				
Temperature	1.260	3.875**				
Wind	−2.851	−2.491*				
Plaza						
1	.559	.173				
2	−5.390	−1.652				
3	9.127	2.970**				
4	12.127	3.346**				
5	−10.961	−2.755**				
6	14.047	5.627**				
7	6.271	2.223*				
Time period			.328	.108	.099	11.998**
11:30 a.m. to 12:00 p.m.	13.665	3.293**				
12:00 p.m. to 12.30 p.m.	22.291	4.713**				
12:30 p.m. to 1 p.m.	29.773	6.215**				
1:00 p.m. to 1.30 p.m.	28.719	5.931**				
1:30 p.m. to 2:00 p.m.	20.966	4.423**				
2:00 p.m. to 2:30 p.m.	15.373	3.144**				
2:30 p.m. to 3:00 p.m.	10.620	1.945				

NOTE: 1 = Monument Plaza; 2 = 101 California Plaza; 3 = Bank of America Plaza; 4 = McKesson Plaza; 5 = Trinity Plaza; 6 = Fremont Plaza; and 7 = 1 Bush Plaza.
*$p < .05$. **$p < .01$.

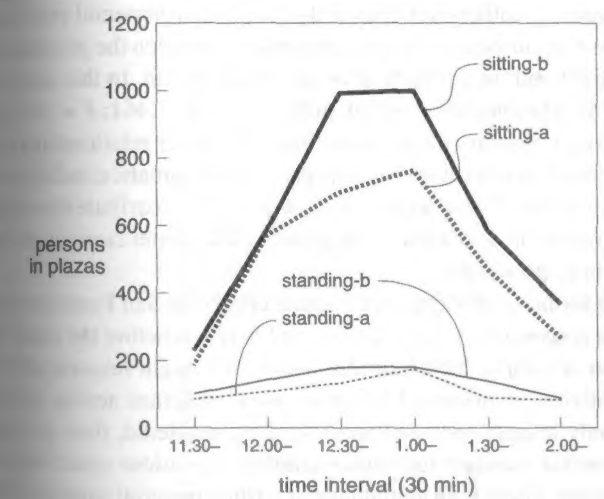

Figure 3: All Individuals Recorded in Plazas at Temperature *a* and *b*
NOTE: Temperature a = 11.7 °C to 15.5 °C (n = 124 censuses). Temperature b = 15.5 °C to 20.5 °C (n = 124 censuses).

higher temperatures. For example, for every person standing at the lower temperatures, there are 4.0 persons sitting, whereas at the higher temperatures, 4.5 persons are sitting. This is consistent with the theory that greater thermal comfort is required to remain seated and is consistent with comparable empirical evidence in Montreal (Zacharias et al., 2001).

We do not know whether a lower level of human comfort is compensated for by a shorter stay over our sample data because stay duration was not recorded. However, in a sample study of Fremont Plaza, stay duration was recorded for 100 individuals across a temperature range from 16.7 °C to 23 °C. No significant correlation between stay duration and temperature was found for this sample, with the mean stay at 20 minutes and standard deviation at 14 minutes. Observation suggests that other factors, such as an ongoing conversation, lunch with another person, or reading material, lead to longer stays. Because of these other factors, a much larger sample of individuals will be needed to determine whether a relationship exists between stay duration and microclimate.

It is sometimes suggested that a variety of environmental conditions is desirable for the urban plaza because people have different needs at different times and because the complex nature of these needs is best met with a variety of landscape and microclimatic conditions. If this is so, then we might expect that over time and place and in relatively clement conditions, people will

distribute themselves rather evenly over the local environmental conditions. For example, we might expect a linear relationship between the proportion of people in sunlight and the proportion of the plazas in sun. In this sample of seven plazas, the relationship is indeed quite strong ($R^2 = .461$; $F = 156.2$; $p <$ .0001). However, it appears more likely that a nonlinear relationship exists. For example, people will visit plazas with poor microclimatic conditions less often, as shown below. Those who do visit will tend to distribute themselves over varying conditions in the plaza but gravitate into better conditions when they become more prevalent.

Is the claim for more stringent open-space criteria in San Francisco justified? If unique responses were to be observed here—whether the cause was acclimatization or simply high humidity—then we might respond affirmatively. Alternatively, if observed behavior were invariant across environments when only temperature and sunlight are considered, then we might consider a universal standard for human comfort in outdoor space based on these factors alone. There is an abundance of written material suggesting that San Francisco's environment is unique, where human comfort is concerned. For example, whereas temperatures remain moderate throughout the year, they seldom exceed 22 ° C. Although it is often said that San Francisco is a humid city, relative humidity varied between 59% and 61% during our census months, whereas in Montreal, the comparable figures were 52% and 65%. No significant differences in wind were detectable in the two samples, and humidity on site was not measured.

The temperature ranges compared are 12 °C to 22 °C in both cases, divided into five 2-degree intervals. The rates of participation in activity for the two cities are compared in Table 3. It will be seen that the proportions of plaza users engaged in the same activities are relatively similar in the two cases, with only 3 cases of significant difference out of 24 paired data sets. The response in each city to local conditions when only temperature is considered is the same. We therefore reject the claim that high relative humidity in San Francisco requires special environmental countermeasures to induce public presence in plazas. Rather, temperature and sunlight remain virtually the only measurable environmental factors in human presence and activity.

MICROCLIMATE VERSUS SOCIAL FACTORS IN THE DISTRIBUTION OF PEOPLE

The area in the sun is calculated for all plazas so that the area per person can be determined. This density figure is treated as a dependent variable, with

TABLE 3
Plaza Behaviors in San Francisco and Montreal as a Function of Temperature (in proportion)

	In the Sun						In the Shade					
	Standing		Sitting		Total		Standing		Sitting		Total	
Temperature Interval[a]	SF	Mtl	SF	Mtl	SF	Mtl	SF	Mtl	SF	Mtl	SF	Mtl
12–14	.166	.173	.638	.664	.804	.840	.066	.040	.130	.120	.196	.160
14–16	.161**	.076**	.637	.665	.799	.740	.060	.060	.141	.200	.201	.260
16–18	.114	.136	.666*	.739*	.779	.880	.055	.020	.165	.100	.221	.120
18–20	.113	.082	.472	.638	.585	.720	.113	.050	.301	.230	.415	.280
20–22	.083*	.044*	.593	.492	.676	.540	.037	.060	.288	.410	.324	.460

NOTE: SF = San Francisco; Mtl = Montreal.
a. Temperature intervals are measured in degrees Celsius.
Significant differences between cities: $*p < .05$. $**p < .01$.

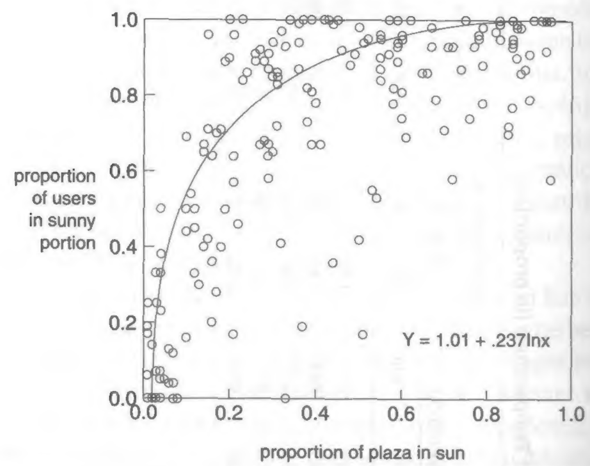

Figure 4: Proportion of Plaza Users in the Sun as a Function of the Proportion of the Plaza in the Sun

plaza, time, and temperature treated as independent variables in a multiple regression. There is no significant relationship between area per person and any of these variables. The mean area occupied is 73 m^2, with a standard deviation of 68. If people were thought to distribute themselves across the plaza such that space was more important than sun, then one could expect a linear relationship between the proportion of the plaza in the sun and the proportion of plaza users in the sun. However, the relationship is clearly nonlinear and is in fact rather complex (see Figure 4). The best fit for regression is logarithmic, as illustrated in Figure 4 (R^2 = .746; p < .0001). As more plaza space becomes sunlit, a proportionately higher number of users are found there, whereas virtually all users are found in sunny areas when the proportion of the plaza in the sun is as low as .30. It can be concluded that there are upper limits to crowding in the most favorable conditions, but users will gravitate to those spaces when they become available.

The preference for sun in public space can be looked at another way. Sunny areas have 4.5 times as many people per unit area as shaded areas across the entire sample. Because the plaza benefit must be evaluated in most planning negotiations, the plaza areas in sun or shade could be weighted using values such as these.

We might also examine only those areas actually hosting people. Is there a difference in the density between those habitually occupied areas in the sun and those in shade? The units were 9 m^2 squares laid at random on the plan. The highest density was found on parallel benches facing the sun such as in

McKesson Plaza, where there were as many as 15 people seated within 9 m^2. It is perhaps obvious that the plazas where the greatest proportion of the surface area was in use were also those with the highest levels of use overall. Less obvious is the fact that the proportion of surface area in use is closely related to the proportion of the plaza area in sunlight over time (see Table 4). The mean number of people per square in sunlight was 3.34, and the number of people per shaded square was 2.15, a significant difference. It is clear that people have a higher tolerance for others in sunlit areas than they do in shaded areas. It is worth noting at the same time that only a small part of each plaza actually hosts people over time and environmental condition.

Because local residents or workers have preformed ideas about the plazas within walking distance (e.g., some are regarded as pleasant, bright, and sunny, whereas others are seen as windy or dark and cold), a general impression may be gained simply by general levels of sunlight. Choosing to visit a plaza may then draw on a preformed impression about the sunlight levels in the plaza. In our case, we considered time periods separately but combined all temperature levels. The total visit rate for the plaza was related to the metric area in sunlight (R^2 = .223; F = 14.312; p < .0004), whereas the relationship between total visit rate and the metric area of the plaza was not significant in our sample. It must be concluded that people do generally favor plazas with higher levels of sunlight, whereas the size of the plaza is not significant in preference. Location factors and surrounding land uses could be important in these decisions. In this study, we tried to control for these factors by considering only plazas that were close to each other within the downtown core.

The second social factor considered in the distribution of people was smoking behavior. We might expect, given the public discourse on the dangers of consumption of second-hand tobacco smoke, that smokers would be spatially segregated from nonsmokers. We might also expect that habitual behavior of both groups would lead to a pattern of use across the plaza. Although there is no enforced segregation, people may organize themselves collectively for a number of possible reasons. Of immediate interest is the effect the presence of smokers may have on the use of the environmentally preferred parts of the plaza.

The Bank of America Plaza, with a relatively high proportion of smokers, was chosen to see whether patterned spatial segregation existed. The same spatial units were used as in the previous analysis. Individuals within the 61 units were sorted into the following categories: smokers without nonsmokers present, smokers with nonsmokers, and nonsmokers without smokers. There is substantial segregation of the users. Of the 142 smokers, 111 were alone or with other smokers only, whereas 31 smokers were with 73 nonsmokers. The

TABLE 4
Substudy of Sun and Shade

Plaza	In the Sun: Number of Squares (9 m²) per Plaza	Number of Plaza Censuses	In the Shade: Number of Squares With People	% of Squares in Use
Monument	33	29	232	24.2
101 California	39	54	414	19.7
Bank of America	60	29	317	18.2
McKesson	40	20	333	41.6
Trinity	13	34	186	18.3
Fremont	25	33	311	37.7
1 Bush	59	31	386	21.1

NOTE: Area in use explained by % area in sun = 67%; $F = 10.078$; $p = .02$. People per unit area (9 m²) in the sun = 3.34 (±0.18); people per unit area (9 m²) in the shade = 2.16 (±0.11). For both, there is a 95% confidence interval.

remaining 1,298 nonsmokers were not with smokers. However, the smoking users were not responsible for displacement of others in the plaza. Smokers form the majority (more than 23%) of the plaza surface, although they constitute only 10.4% of the total population in 37 censuses (only the 1998 census included smoking activity). Their preferred locations are those largely rejected by the majority users.

Examination of Trinity Plaza shows the same pattern: 53 smokers alone, 12 smokers with 33 nonsmokers, and 300 nonsmokers alone in their spaces. Although 16% of the users smoked, they formed the majority in 11% of the plaza area, all of it located in permanent shade.

MICROCLIMATE VERSUS LANDSCAPING DESIGN IN PUBLIC PRESENCE

One of the plazas, the A.P. Giannini Plaza at the Bank of America, underwent major redesign between our earlier census and the later one. This plaza is famous or infamous for being located almost entirely on the shady but prestigious California Street frontage of the office tower (see Figure 5). Masayuki Nagare's well-known sculpture officially known as Transcendence but known popularly in the city as the Banker's Heart, is a black granite monolith lying on the stone floor of the plaza. In the earlier design, a few unsittable concrete planters were distributed across the floor of the plaza, and nothing else but steps and the outer ledges were provided for sitting. In an effort to bring life to the plaza in front of the building, substantial investment was made in a redesign of the surface materials and furnishings to attract people. Only the California Street plaza area was redesigned, as illustrated in the figure. The so-called stone heart was laid on a planter filled with grass, and the planter edge was made sufficiently large to allow sitting. New bench and planter groups were introduced. The benches are large, classic, garden wood benches, arranged in groups and protected from prevailing breezes by bamboo. Many more sittable planters now line the area in front of the columns to the building, softening the hard edge between plaza and building from the typical California Street approach. The sunlight strikes the seating area at the peak use time around noon, at the same time as the back of the building, where most of the plaza users are located.

The uses of the redesigned part of the plaza and the plaza in the original condition were studied before and after redesign. Because the intended effect was to bring more people to the redesigned, front side of the plaza, we simply

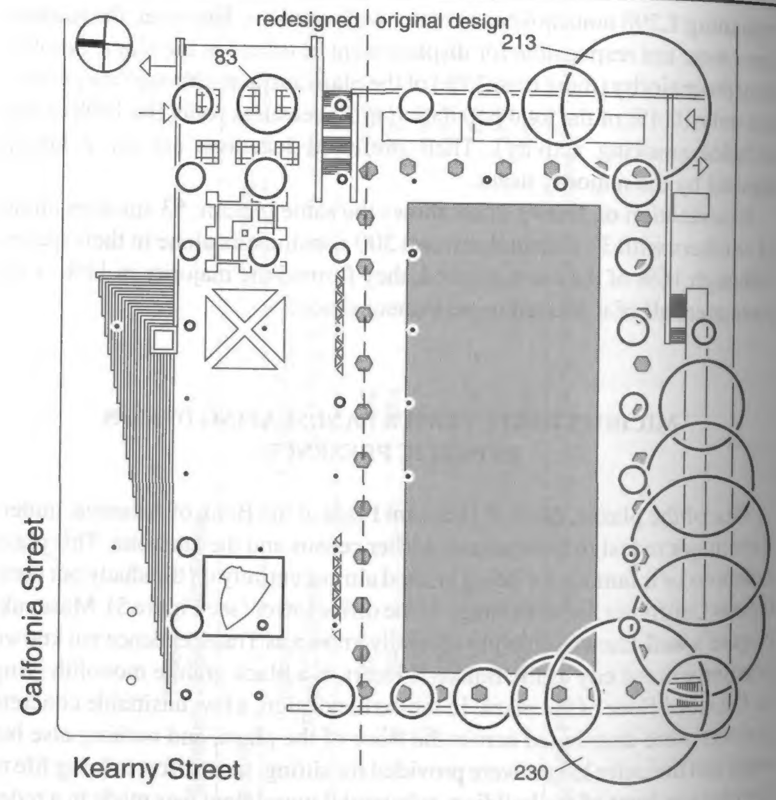

Figure 5: The Bank of America Plaza, 555 California St., San Francisco
NOTE: All individuals counted within 9 m^2 squares over 54 censuses, represented by the size of the circle.

examined the proportion of the users located there before and after the redesign.

As can be seen in Table 5, a slight but significant increase was observed in the use of the redesigned part of the plaza. Whether the return in use level justified the investment is for others to judge. Whether the visual improvements are appreciated by San Franciscans and compensate for a history of inimical feelings toward the building and the plaza has not, to our knowledge, been assessed.

Finally, we consider whether the provision of seating surfaces is a major factor in human presence in the plazas. Whyte (1988) observed that the

TABLE 5
Before and After Use of the Redesigned Part of the Bank of America Plaza

M Proportion of Users Before	*M Proportion of Users After*	*Number Before*	*Number After*	*t Value*	*p Value*
.162	.249	17	37	−2.319	.0244

TABLE 6
The Effect of Seating Provision on Public Presence

	Regression				ANOVA	
N	R^2	df	SS	MS	F Value	p
193	.363	3	38,982.099	12,994.032	41.329	< .001

NOTE: SS = sum of squares; MS = mean of square.

Table 7
Regression Coefficients for the Effect of Seating Provision

Intercept	t	*Temperature*	t	*Sun*	t	*Seating*	t
-6.360	-.766	2.208	4.363	.071	8.126	.201	5.650

NOTE: Each *t* value refers to the preceding coefficient.

"effective carrying capacity of plazas" was less than the real capacity in his study of New York corporate plazas. In our study, all ledges, walls, planter edges, and benches where people could sit were included, along with steps, if it was seen that the steps were actually used for this purpose. The total length of such surfaces was calculated for each plaza. In the case of steps, three rows counted as a single sitting area, whereas the sitting ledges at 101 California Street were reduced from five to two, based on the observation that people never sat more than two deep. Bench provision varies considerably among the plazas, with 141 m of bench in Bank of America Plaza and just 23 m in Trinity Plaza.

Stepwise multiple regression was performed, using time of day, temperature, seating, and area in sun as independent variables. As predicted from the previous study, time and temperature have a preponderant effect. The amount of seating has a very modest impact on public presence (see Tables 6 and 7).

DISCUSSION

Microclimatic conditions in San Francisco are much more uniform than they are in many other North American cities. Although a positive linear response to rising temperature and increasing sunlight observes the trends found elsewhere, nonlinear trends cannot be seen. It could be argued that the temperatures experienced in the city are within a range where sunlight has a positive (i.e. use-inducing) effect. In cities experiencing higher normal temperatures, more shade will be desired. These variations in local response and need, however, can now be subsumed within a single response model.

It is conventional wisdom that people exposed on a long-term basis to prevailing cold conditions evaluate extremes of heat and cold differently than do people experiencing sustained hot conditions. These two studies confirm that spatial behavior as an indicator of human comfort is invariant across two quite different climatic regimes. It would be very useful to know whether subjective evaluations of identical conditions by two such groups of people vary. For example, we need to know how to interpret the subjective scales now being developed for evaluation of various environmental stressors.

The preliminary attempt at combining social and design factors with microclimatic variables in this study represents the typical situation encountered in environmental studies. Because many such studies are driven by the need to make environmental decisions, we will need to understand better the relationship between physical and social factors. Although we merely examined how smoking and nonsmoking users interacted, any number of other identifiable groups of users could be examined in the same way. It would also be useful to examine the impact of activity programs on people's presence in relation to microclimatic and design factors. Whyte (1988) recommended that such activities were essential in promoting a sustained pattern of use and the management of pathologies. His suggestions have inspired the corporate takeover of some public space, such as Sony Plaza at the former AT&T Building in New York City. Therefore, such ideas now require systematic study before they become untested prescriptions.

The specific study of environmental design carried out in this study provides only highly preliminary assessments of the effect size of environmental design in relation to microclimate. A useful next step would be a study of a larger sample of open spaces before and after redesign. Although many preference studies of environmental design have been conducted, there remain very few quantified studies of use and still fewer studies of use controlling for the design itself.

CONCLUSION

If this study of spatial behavior in downtown open spaces in San Francisco can be considered a test of the widely stated reasons for the requirements brought into effect in 1985, we can state that, in general, such requirements were called for. The relatively low proportions of plazas in sunlight have an inhibiting effect on use. Clearly, maximizing the areas in sunlight should be a far higher priority than adding to the stock of open space.

It is not apparent that open-space users in San Francisco exhibit unique behavior, regardless of the reason. Microclimate has the same importance in spatial behavior in two cities where the temperature, humidity, and sun conditions are substantially different. At least in these two temperate climate cities, air temperature and sunlight account for much of the variance in behavior. Although the presence of wind clearly acted as a use inhibitor in both these case studies, a study that more carefully measured wind effects and spatial behavior would be desirable, particularly in light of the standards in effect in most cities. The results of the present study, together with the previous one, suggest the invariability of human physiological responses across microclimatic regimes.

This study did not reveal that the provision of seating in plazas had a significant effect on plaza use. Again, in relation to the principal factors of temperature and sunlight, the amount of seating provision is unimportant. Rather, the quality and position of such seating will largely determine whether it is used.

REFERENCES

Benedetti, F., Colombo, C., Barbini, B., Campori, E., & Smeraldi, E. (2001). Morning sun reduces length of hospitalization in bipolar depression. *Journal of Affective Disorders*, *62*, 221-223.

Butler, A., & Nicholson, R. (2000). The effects of sunlight are both beneficial and detrimental to human health. *Chemistry in Britain*, *36*(12), 34-36.

Cherulnik, P. (1993). *Applications of environment-behavior research*. UK: Cambridge University Press.

City and County of San Francisco. (1985). *Downtown: An area plan of the master plan of the City and County of San Francisco*. San Francisco: City of San Francisco.

Dosher, B. A., & Lu, Z. L. (2000). Noise exclusion in spatial attention. *Psychological Science*, *11*(2), 139-146.

Hall, E. T. (1966). *The hidden dimension*. Garden City, NY: Doubleday.

Koushki, P. (1988). Walking characteristics in central Riydah, Saudi Arabia. *Journal of Transportation Engineering*, *114*(6), 735-744.

Leather, P., Pyrgas, M., Beale, D., & Lawrence, C. (1998). Windows in the workplace: Sunlight, view, and occupational stress. *Environment and Behavior, 30*(6), 739-762.

Liden, E., Mander, A., Deniz, F., Gunnarsson, A. G., Nordin, S., & Hogman, L. (1997). Odor-annoyance estimates from road-traffic combustion exhausts: Calibration with master scaling using pyradine as a reference. *Environment International, 23*(6), 829-837.

Mace, B., Bell, P. A., & Loomis, R. J. (1999). Aesthetic, affective and cognitive effects of noise on natural landscape assessment. *Society and Natural Resources, 12*(3), 225-242.

Roberts, D. (2001). The healing sun: Sunlight and health in the 21st century. *Journal of Epidemiology, 30*(3), 632-633.

Rotton, J., & Cohn, E. (2000). Weather, disorderly conduct and assaults: From social contact to social avoidance. *Environment and Behavior, 32*(5), 651-673.

Stallen, P. (1999). A theoretical framework for environmental noise annoyance. *Noise and Health, 1*(3), 69-80.

Tanaboriboon, Y., Hwa, S., & Chor, C. (1986). Pedestrian characteristics study in Singapore. *Journal of Transportation Engineering, 112*(3), 229-235.

Vettel, S. L. (1985). Environmental and urban design values in central business district regulation. *Ecology Law Quarterly, 12*, 511-566.

Walmsley, D. J., & Lewis, G. J. (1989). The pace of pedestrian flows in cities. *Environment and Behavior, 21*, 123-150.

Whyte, W. (1988). *City: Rediscovering the center.* Garden City, NY: Doubleday.

Zacharias, J., Stathopoulos, T., & Wu, H. (2001). Microclimate and downtown open space activity. *Environment and Behavior, 33*(2), 296-315.